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SCHEDULING REFRESHER-BASED RESCUE AND EVACUATION TRAINING FOR WIND TURBINE TECHNICIANS

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Abstract: The adage “once trained, always trained” is a recognized myth. A look at the refresher skill training of wind technicians show that rescue and evacuation skills deteriorate over a period of time of non-practice. Therefore, the importance of safe and efficient rescue and evacuation of wind turbine technicians working at height cannot be over emphasized. An evaluation of the wind technicians’ skill and knowledge proficiency in the use of rescue and evacuation devices after acquisition indicates that poor retention of technician skill in the safe and procedural execution of a rescue during an emergency is a potential problem that is yet to be addressed. This research quantitatively assesses if wind turbine technicians are capable of retaining knowledge and skills learned over a 24 month period, evaluates pre-acquisition, acquisition and follow-up primary measurements at retention intervals of one and three months and proposes a refresher timeframe and benchmark performance that can maximize the proficiency level of technicians. Due to the infrequent nature of practically carrying out on-the-job rescue and evacuation roles, there is a likelihood of skill and knowledge decay in times of significant emergencies except where there is a support system available to the technicians. Possible solutions to overturn these problems are discussed based on the data obtained during the study. Draft results were used to propose a refresher timeframe and benchmark performance that can maximize the proficiency of technicians to an acceptable level as guidelines for management towards scheduling safe wind turbine rescue and evacuation training.

1 INTRODUCTION & BACKGROUND

Skill decay after periods of non-use or non-practice is well known and has substantial implications when relatively long periods of time separate training from the application of learned skills, (Hall, Stiles and Horwitz 1998). Skill retention is significant because of the time that potentially separates skill acquisition and use of the same skills on the job. Without comprehensive evaluation of performance, accurately identifying and predicting skill decay is not feasible.

Researchers have spent a considerable amount of time identifying the relevant factors that affect skill retention, (Arthur Jr., et al. 1998). This is, for the most part, a practical decision because determining the quantitative relation requires greater expenditure of resources in terms of time, equipment, test subjects, etc. Among the factors that have been examined are: length of retention interval; task characteristics; methods of testing for original learning and retention; conditions of retrieval; use of mnemonics and other task aids; prior experience (Arthur Jr., et al. 1998). There are several job situations that demand the application of skills that have not been used over extended periods of time. Despite the apparent importance of skill retention on performance, however, few empirical studies have tested factors that mediate skill retention in the wind energy sector. Other factors such as extended practice of skills have been associated with increasing skill retention. While practice has been established as a strong predictor of skilled performance, it has not been established whether reliable contexts, such as those found on the job, are related to retention. The work of Hurlock and Montague (1982) concluded that most skill deterioration is the result of several factors which include level of initial learning, non-utilization periods, skill type, events during skill non-use, and lack of effective feedback.

However, some types of skills tend to be better retained than others e.g. the two kinds of motor skills – *continuous and discrete*. Continuous motor skills are those involving the repetition of a movement pattern with no distinctive start or end (e.g. riding a bicycle) while procedural task which is the main focus of this study are a series of discrete responses, such as operating a rescue and evacuation device system, moving a gear shift etc. Another significant difference is that continuous motor skills decay slowly over a period of months and years while discrete/procedural skills decay rapidly over a period of days, weeks or months. Unlike continuous motor skills, procedural proficiency cannot be maintained in the absence of practice (Schendel, Shields and Katz 1978). Though these responses are usually self-paced and easy to execute, the main problem for the learner is response selection, i.e., deciding what responses to make and in what sequence to make them. In general, the retention of procedural tasks, the sequencing of tasks, and the ability to perform a task in a required time period deteriorate rather quickly.

Skill retention can be addressed using the concept of comparison of performance before, during and after a period of controlled activity – regarded as the retention interval. Performance measurements can vary from different studies and tasks, but ideally, it is based on combinations of speed, accuracy, and the number of procedural steps the subject can correctly recall. An individual's post-training score on a performance test, combined with the length of the retention interval, according to (Bodilly, et al. 1986) is considered the best predictor of skill retention. Refresher training is typically used to stabilize the effects of forgetting and maintaining proficiency of skills. The significance to this study is to determine the rate at which skills decay, and schedule refresher training such that proficiency does not decay below an acceptable benchmarked performance. Schendel and Hagman (1980) stated that extra training enhances retention regardless of whether it is provided during the initial training or in a refresher training session at some point during the retention interval. Practical issues of cost and availability of personnel however, require that refresher training be conducted in an efficient manner that will both reduce the probability of further accident happening during rescue procedures and reinstate the performance levels of the technicians.

Strategic components of skills and knowledge should be periodically evaluated and supported to determine whether they meet the ever changing needs of the learners and to ensure effective training. Therefore, training needs analysis (TNA) which is a systematic assessment of training can affect improvement in the knowledge, skills or attitude of individuals or teams in the workplace, (Drummond 2008). It forms the basis for structured training and identifies current work-based 'training gap' or problems in performance standards that may be resolved through training. TNA identifies the current standard of performance being achieved, and the required standard of performance with the aim of attaining such standards through the scheduling of refresher trainings. The cost of training technicians to an organization when taken into account can be significant in terms of instructor time, cost of preparation, participant time, materials, training venues and equipment etc. Therefore, the money and time may not yield a satisfactory performance benchmark if the training gap of the technicians have not been clearly identified and defined i.e., training objectives, training plans and training programs which are designed based on identifying their training needs.

There is currently no procedure in place to determine skill deterioration, or refreshing needs of wind turbine technicians that will enable efficient technician refresher training decisions. Therefore, this research aims to propose a timeframe for considering when and how often such rescue skills should be refreshed for a 'benchmark of good practice'. The industry assumption is that wind technicians maintain their individual skills over time and are ready to use such skills whenever needed in carrying out on-the-job rescue and evacuation roles. If this assumption does not hold, then the employers may wish to initiate an effective refresher training program.

A study conducted by Prophet (1976) concluded that the time needed to refresh is less than the time needed for original training. This finding also supported by Shields, Goldberg and Dressel (1979) found that even with skill decay following a no-practice interval, residual skills still remain. In addition, Rose, et al. (1981) found that tasks that were supported by job aids i.e. written materials that are used in the normal performance of the job were retained longer.

2 STUDY OBJECTIVES

- To quantitatively assess if wind turbine technicians are capable of retaining knowledge and skills learned over a 24 month period.
- To evaluate pre-acquisition, acquisition and follow-up primary measurements at retention intervals of one and three months.
- To propose a refresher timeframe and benchmark performance that can maximize the proficiency level of technicians.

3 METHODS

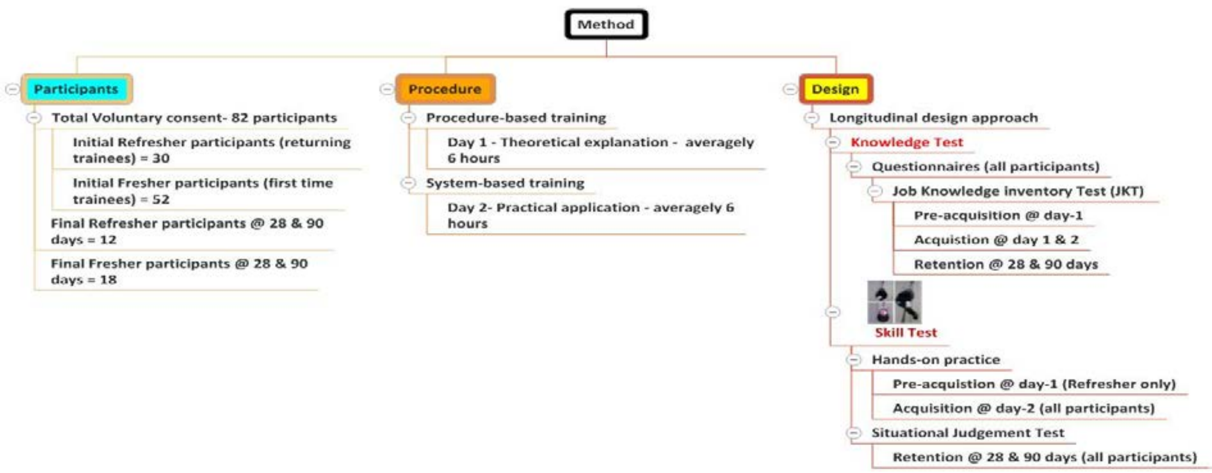


Figure 1: Method of data gathering using basic map explorer

Figure 1 shows the breakdown of the method employed in this study using a simple map explorer. The research participants were those registered to undergo the basic RenewableUK/Global Wind Organization (RUK/GWO) approved height safety and rescue training (purposive-expert sampling) and the study focused on the final 30 wind technicians. ***The 'refresher participants' connote returning trainees while the 'fresher participants' are first time trainees.*** The training was procedure- and system-based averaging 6-hours per day over two-day sessions with emphasis on emergency rescue, how to approach rescue situations in wind turbine generators (WTG) and competent use of rescue equipment. The research implemented longitudinal design approach for data gathering (de Vaus 2001) in order to track changes over time and establish the sequence in which events took place.

Closed-ended questionnaires were designed based on 'Job Knowledge inventory Test' (JKT) (Teachout, et al. 1993). This was used for the entire knowledge assessment from pre-acquisition to retention. Retention measures using JKT was administered online at intervals of one and three months. Skill pre-acquisition and acquisition involved 'hands-on practice' using the automatic constant rate descender (CRD) RG9A, (Lawani, Hare and Cameron 2014b). Only refresher participants were assessed during skill pre-acquisition stage because they have used this device in prior training sessions. Data for skill acquisition was collected for all participants while skill retention assessment was administered online using 'Situational Judgment Test' (SJT) (Lievens, Peeters and Schollaert 2008), with the aid of cued recognition using pictograms to prompt the participants. The participants were required to evaluate the randomized written performance description and the associated pictograms by correctly sequencing the procedural execution of the use of RG9A for rescue and evacuation. These retention assessments engaged participants in the use of computer-based information displayed using two-dimensional (2D) images of the RG9A device. The performances were based on the number of device steps recalled and recognised in the correct sequence (skill) and the number of job knowledge information correctly recalled.

4 RESULTS & ANALYSIS

This study having been piloted, reviewed and amended is based on results of 30 research participants that fully participated all through the assessment period. This reflected an overall response rate of 36.6% out of a total of 82 initial research participants.

4.1 To quantitatively assess if wind turbine technicians are capable of retaining knowledge and skills learned over a 24 month period.

The magnitude of procedural skill and knowledge decay are presented in Tables 1 & 2. The refresher participants display an average of 14.9% and 21.8% decay in skill performance after one and three months respectively while the fresher participants show 19.8% and 29.6% decay in skill performance, (see Table 1). The magnitudes of knowledge decay for refresher participants were 10.5% and 9.5% after one and three months while the fresher participants were 20.4% and 21.4%, (see Table 2). Result of skill (59.8%) and knowledge (30.5%) decay at 24 months reflects the actual mean performance of refresher participants before embarking on the height safety and rescue training (see Table 1 & 2). Figure 2 (a) & (b) depicts the trend estimating that at 24 months retention, refresher participants will retain averagely 35% skill and 66% knowledge competency indicated by the dotted red lines. These 24 month estimates were accomplished using actual pre-acquisition refresher assessment data to generate the theoretical curves describing the path of skill decay.

Table 1: Magnitude of skill retention over one and three month period

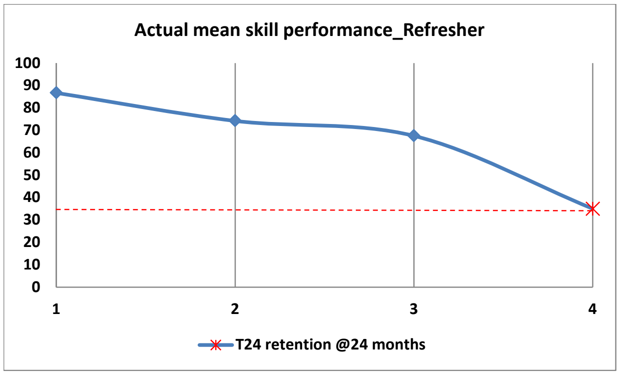
Time	Skill performance (%)		Magnitude of decay (%)	
	Refresher	Fresher	Refresher	Fresher
T_0	35	0		
T_1	87	81		
T_2	74	65	14.9	19.8
T_3	68	57	21.8	29.6
*T_{24M}	*35	*	*59.8	*

*T = extrapolated time at 24 months

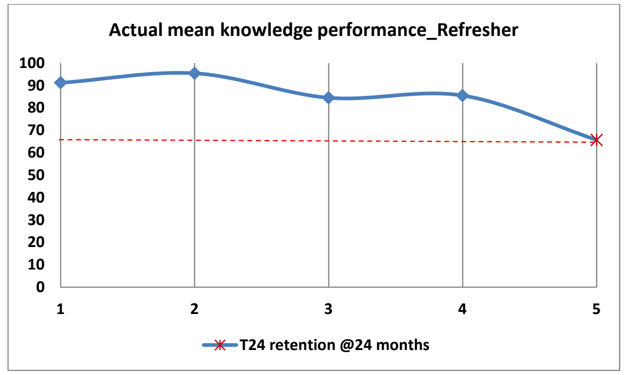
Table 2: Magnitude of knowledge retention over one and three month period

Time	Knowledge performance (%)		Magnitude of decay (%)	
	Refresher	Fresher	Refresher	Fresher
T_0	66	55		
T_1	91	92		
T_2	95	98		
T_3	85	78	10.5	20.4
T_4	86	77	9.5	21.4
*T_{24M}	*66	*	*30.5	*

*T = extrapolated time at 24 months



(a) **Skill Test Score:** 1 = T0 pre-acquisition @ day 1; 2 = T1 acquisition @ day 2; 3 = T2 retention @ 1 month; 4 = T3 retention @ 3 months



(b) **Knowledge Test Score:** 1 = T0 pre-acquisition @ day 1; 2 = T1 acquisition @ day 1; 3 = T2 acquisition @ day 2; 4 = T3 retention @ 1 month; 5 = T4 retention @ 3 months

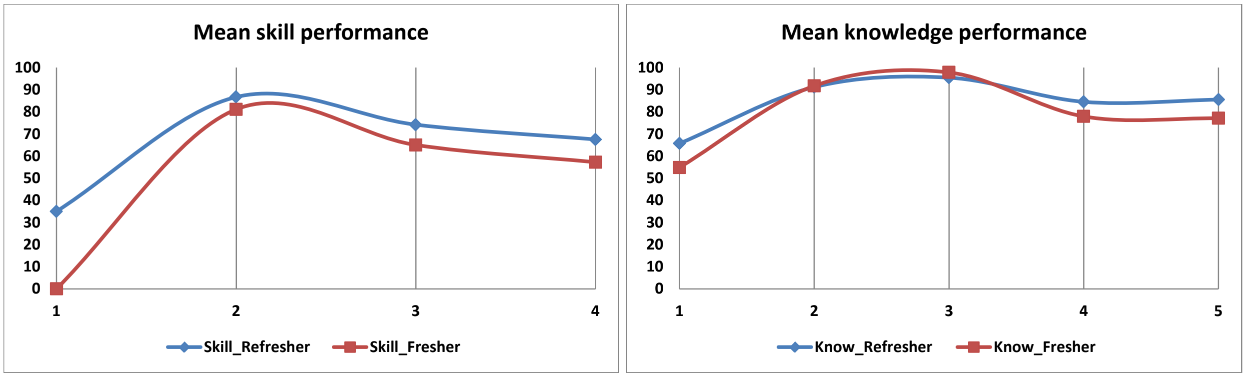
Figure 2: Estimated mean skill & knowledge competency plots for refresher participants at 24 months

4.2 To evaluate pre-acquisition, acquisition and follow-up primary measurements at retention intervals of one and three months

Visual inspection for trends to determine the relationships for both skill and knowledge retention and any possible interactions was done using actual performance data. It was observed that after initial task proficiency, quantitative relationship between a task's factors and its associated performance data at a particular time interval could serve as a generalizable model of skill decay. Figure 3 depicts the mean percentage performance for both skill and knowledge assessment from pre-acquisition to retention highlighting performance trends for refresher and fresher participants. Both set of participants experienced rapid increase in performance score from pre-acquisition to acquisition respectively with peak performances at T_1 (Figure 3a) and T_2 (Figure 3b). The participants experienced significant drop in performance levels for skill and knowledge assessments at one month and gradually dipping toward three month retention. Figure 3a confirm refresher participants outperforming the fresher participants from acquisition to retention periods suggesting the probable influence factor might be due to prior training and experience. Although this study reveals that at acquisition, both refresher and fresher participants can attain almost same level of peak performances (Figure 3b), however, over the retention periods, the probable impact of prior training and experience of the refresher participants seem to enhance their ability to retain knowledge longer than fresher participants. It shows that development is relatively continuous and gradual, and the participants are never at the same level for all skills, (Fischer 1980).

Statistical analysis (knowledge assessment) of tests of normality using Kolmogorov-Smirnov test with conservative alpha level ($\alpha = 0.01$) at T_0; T_1; T_3; T_4 ($p > 0.01$) meet the assumption of normality while T_2 ($p < 0.01$) did not. Levene's test for equality of variance ($\alpha = 0.05$) for knowledge test at T_0, T_1, T_2, T_3 ($p > 0.05$) show that there is not a statistically significant difference between the group's variances. Therefore "Equal variances assumed". T4 with ($p < 0.05$) show variance is significantly different and assumption of equal variance is not met. Independent sample test results ($\alpha = 0.05$) compared the Sig. (p) values for refresher and fresher participants: T_0; T_1; T_2; T_3; ($p \geq 0.05$) indicating that the refresher participants did not statistically significantly perform more than the fresher participants during the knowledge assessment. T_4 ($p \leq 0.05$) conclude that refresher participants performed significantly more than the fresher participants.

Skill tests T_0, T_1 with Sig ($p < 0.01$) did not meet the assumption of normality while tests at T_2; T_3 Sig ($p > 0.01$) satisfy the assumption of normality. Levene's Test for equality of variance ($\alpha = 0.05$) show T_0 with ($p < 0.05$) and conclude there is a statistically significant difference between the group's variances, "Equal variances not assumed". T_1; T_2 and T_3 had Sig ($p > 0.05$) and conclude that there is not a significant difference between the group's variances. Therefore, "Equal variances assumed". Independent sample skill test ($\alpha = 0.05$) for refresher and fresher participants T_0 ($p \leq 0.05$) concludes that refresher participants performed statistically significantly better while performances at T_1; T_2; T_3 ($p \geq 0.05$) indicate no statistically significant difference.



(a) Skill Test Score: 1 = T0 pre-acquisition @ day 1; 2 = T1 acquisition @ day 2; 3 = T2 retention @ 1 month; 4 = T3 retention @ 3 months

(b) Knowledge Test Score: 1 = T0 pre-acquisition @ day 1; 2 = T1 acquisition @ day 1; 3 = T2 acquisition @ day 2; 4 = T3 retention @ 1 month; 5 = T4 retention @ 3 months

Figure 3: Mean performance plots for skill & knowledge from pre-acquisition to 3 months retention

4.3 To propose a refresher time-frame and benchmark performance that can maximize the proficiency level of technicians

The education sector has a history of setting 75% as the benchmark for passing score (McKnight 1999). This study adopted Table 3 as guideline for diagnostic assessment of performance benchmark at limit state of 70%. The structure implemented for carrying out these assessments for benchmarking skill and knowledge is shown in Figure 4. Mean skill performance score for refresher participants at one and three months were 74% and 67.5% while the fresher participants performed at 65% and 57.22%, (Figure 5a). The skill performance at one month for refreshers at 74% was above the 70% threshold which this study considers as the limit state performance, while at three months, it falls short (see Table 3). The fresher participants performed below this threshold. Results for knowledge performance (Figure 5b) show that the mean retention score for the refresher participants at one and three month was 84.5% and 85.5% while the fresher participants performed at 77.9% and 77.1% which are above the 70% benchmark considered as the limit state performance. This indicates that the participants are capable of retaining their knowledge up to three months after acquisition.

Table 3: Proposed diagnostic performance benchmark

Grade %	Description
80-100	Outstanding demonstration of learning outcomes
70-79	Excellent demonstration of learning outcomes
60-69	Comprehensive demonstration of learning outcomes
50-59	Satisfactory demonstration of learning outcomes

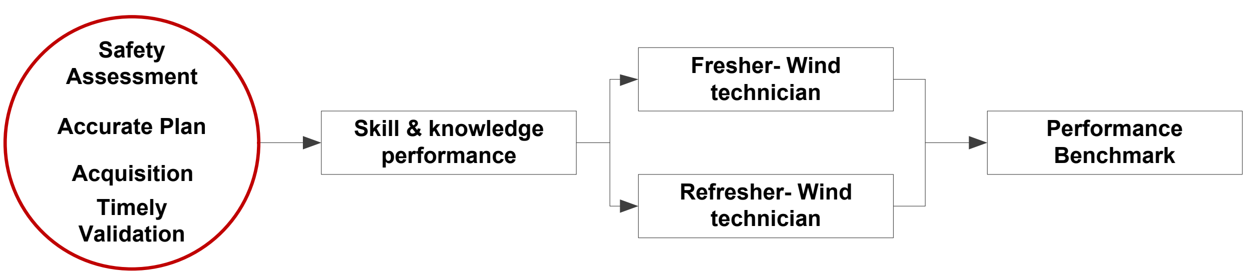
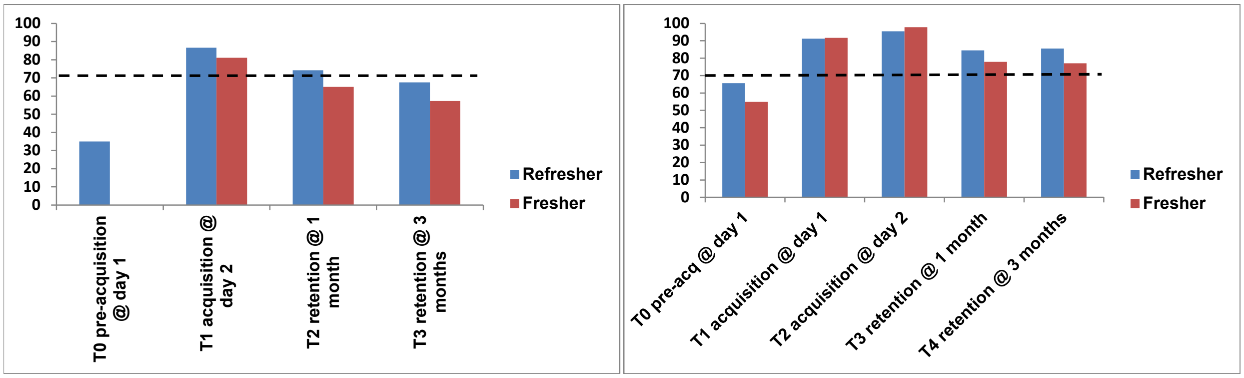


Figure 4: Performance benchmarking structure for skill and knowledge retention



(a) Mean Skill Performance Test Score **(b) Mean Knowledge Performance Test Score**

Figure 5: Mean performance plots for skill & knowledge from pre-acquisition to 3 months retention

5 DISCUSSIONS

The results of this study build on existing knowledge by extending skill decay theory to field-based application. Further, empirical data has been used to identify the actual magnitude of procedural skill decay. Significantly, the magnitude of procedural skill and knowledge retention declined rapidly after one month and gradually toward three month. This is comparable with the study of Wetzel, Konoske and Montague (1983) which reveal that immediately after training and a four weeks interval, participants had a 21% drop in scores while Austin and Gilbert (1973) observed a 16% loss of basic problem solving skills after 8 weeks. A common construct regarding this is based on the feedback the trainees receive during acquisition (Ramaprasad 1983; Gibbs and Simpson 2004; Sadler 2010). When such feedback contains information about the magnitude and direction of performance errors, it directs the trainees towards ways of correcting the error and improving their performance while the infrequent or the total absence of feedback is associated with skill and knowledge loss, (Hurlock and Montague 1982; Driskell, Willis and Copper 1992). Another factor, whether direct or an intervening variable, is the time interval between training and performance. It is therefore not startling that the longer the time interval between practice and performance, the greater will be the skill decay. This study revealed that rescue skills decay over time where performance decreases rapidly soon after training then occurring at a slower rate, which is similar to results reported in the works of (Arthur Jr., et al. 1998; Wixted and Ebbesen 1991). According to (Driskell, Willis and Copper 1992; Wixted and Ebbesen 1991), this pattern appears to be consistent across a variety of skills and tasks. Previous skill retention research has sought to identify factors that influence the rate of individual skill decay (Rose, et al. 1985; Wisher, et al. 1991). If tasks could be reliably described according to these factors it would then be possible to examine, using actual performance data, how particular combinations of factors influence performance at some time interval (e.g. 24 months) after initial task proficiency had been achieved.

Learning is characterised by an initial steep learning period that asymptotes to maximum proficiency, while forgetting is characterised by an initial steep drop in proficiency, which then levels off, dropping more slowly as time goes on (Stothard and Nicholson 2001). According to Stothard and Nicholson (2001), the major decay in skill occurs in the first few weeks/months after training, with smaller differences over time. Findings from this study which are based on in-situ real life field data validates that the theory of skill decay is correct with proficiency dropping between time zero and three months. This confirms the results of Stothard and Nicholson stating that the drop in proficiency was greater between time zero and three months, than between the sixth and eight month as suggested by others. ‘Forgetting’ over the three-month period occurred at different rates for refresher and fresher participants. The refresher participants tend to perform better on average than the fresher participants as depicted in the mean plots for both skill and knowledge tests. It should be noted that the degree of successful performance of an individual on any of these tests is largely reliant on the learning experience, or the type of practice and instruction received. Also, this study identified that task steps that are forgotten tend to be those that are not suggested by the previous sequence of steps or by the equipment and Shields, Goldberg and Dressel

(1979) identified these as amongst factors accountable for differences in retention. The initial level of learning which is obviously related to the amount of initial training is one of the most important factors in determining retention (Hurlock and Montague 1982). An individual's level of initial proficiency has a direct relationship with the level of skill retention, and relation between recall success and skill level (Watson and Fischer 1977). Other contributing factors to procedural skill decay of wind technicians could be associated to their peripatetic nature of work which has limiting factors in this research; practice; aptitude; equipment design and task difficulty. Safe working requires robust procedures and it is suggested that training, practice and experience are major contributing factors influencing procedural skill decay during rescue and evacuation. This study also discovered that technicians mostly forgot task steps at the beginning and end of a task and steps related to safety and this was validated by the work of Osborn, Campbell and Harris (1979). Different literature has shown that skill retention for all tasks deteriorates; and the rate of retention differs by task characteristics. Tasks with performance that deteriorates rapidly tend to be procedural tasks which involve a number of steps, have no performance cues, and have time requirements similar to the use of the RG9A device while tasks with performance that deteriorates more slowly are continuous tasks with cues or an obvious internal logic. Ericsson and Lehmann (1996) pointed out that the attainment of exceptional performance is usually accompanied by sustained, deliberate practice and this is not possible with the technicians as the rescue device is considered as being deployed and not fit for purpose if taken out of the airtight storage bag. A central feature of deliberate practice is in the setting of performance goals and the application of practice strategies to attain these goals. Learners also make use of feedback to adjust the quality of practice and feedback is considered critical to remembering information, and timely and accurate feedback will enhance the ability of a learner to retain a skill.

Scheduling refresher training is costly, entailing time, personnel, and equipment costs which are necessary when training is periodic. For refresher training to be effective, technicians need to experience a range of job situations involving information or skills previously acquired but impaired through non-practice. Job-like problems should be varied and practice in solving them should provide feedback on the quality of performance. People generally need feedback, or “knowledge of results” to correct errors, observe and use cues associated with task performance, and generate effective procedures (Hurlock and Montague 1982). Therefore, implementing the proposed benchmark performance of 70%, it is advisable that refresher participants be scheduled to undertake rescue and evacuation practice drills within three to six months after skill acquisition. For fresher participants, it is recommended that they undertake an early practice drill within one and three months after skill acquisition to restore their proficiency to optimum. Performance benchmarking should be a continuous process of validating technician's performance to determine best practice and to establish process goals for improvement. Determining the limit state performance which is considered as the critical margin of safety performance for wind technicians involved four steps (see Figure 5): the ‘safety assessment’ of key competencies and the ability to perform those competencies within a specific task safely; the ‘accurate planning’ of an achievable path that a technician can follow to maintain or improve identified competencies by mapping strengths and weaknesses; the ‘acquisition’ of skills and knowledge required to maintain or improve identified competencies; and lastly, ‘timely validation’ of performance-based test conducted to determine if a technician retained proficiencies three months after skill acquisition. This structured approach towards benchmarking skill and knowledge can serve as a standardized scenario within which collective or individual performance can be assessed frequently as required to maximize basic skills and knowledge. Therefore, a limit state performance benchmark of 70% indicates that the study participants barely attain this limit after one month of skill retention assessment while their knowledge performance was beyond the outlined benchmark. It should be noted that even one error can be fatal in a rescue e.g. participant could score 80% which is a pass but the 20% wrong can result in fatality.

6 CONCLUSION

The skill and knowledge assessment is a strategy for sustaining technicians’ readiness toward efficiently using the RG9A device in carrying out rescue during periods of emergencies whilst working at height. Dynamic simulation technique is a favoured approach that can be applied to boost the strategy for refresher training rather than static representations (pictographs) used in this research. When employed, such techniques can provide training of progressively greater complexity and realism. Dynamic simulation will permit technicians to apply real world and real time decisions to specific rescue and evacuation problems and to observe realistic responses to those decisions.

The principal application of this study addresses the facilitation of instructional and practice strategies that can lead to competent application of acquired skills and knowledge in the field. This is beneficial for practicing procedural skills that require timing and precision that can only be acquired through deliberate practice with authentic tasks.

Data on the feasibility of using technician-generated retention estimates to facilitate predictions about the scheduling of refresher training timeframes are suggestive, but not absolute. In general, the literature indicates that, in the absence of practice or other reinforcement, skill retention declines over a period of time. Since relearning or refreshing of skills can take significantly lesser time than original learning; this study has attempted to estimate relearning needs of wind technicians by adopting a benchmark performance and tentative timeframes for scheduling refresher trainings. Given that skill decay will occur even if wind technicians are over-trained, another approach of defining means to optimize the schedule of refresher training is needed so that technicians will receive training when needed to preclude them from falling below a set criterion level of performance. This can be accomplished by instituting the type of assessment used in this research where the technicians are required to carry out a situational judgement test and job knowledge inventory test as a function of estimating their training needs.

This assessment can also be used as ways of examining and predicting skill retention with the ultimate goal of improving the sustainment of performance or readiness. This study therefore recommends two comprehensive approaches to sustaining skill and knowledge of the wind technicians: enhancing initial learning, enhancing the prediction of skill retention for effective scheduling of refresher training thereby reducing the rate of skill decay. This can be achieved through the development of these potentially practical and accurate means of predicting skill decay to aid the scheduling of refresher training.

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